Do quark stars exist?

Bezverkhniy Volodymyr Dmytrovych.

Ukraine, e-mail: bezvold@ukr.net

It is very likely that classical quark stars cannot exist by definition. Unfortunately. But, there are nuances... All this can be strictly calculated. Let's consider in more detail.

Earlier it was shown that in black holes, under the influence of high pressure, baryonic matter turns into quark-gluon plasma [1]. That is, a black hole consists of a small core (a “drop” from QGP) and a large gravitational radius. Moreover, the radius of the core of the quark-gluon plasma will be either equal to the gravitational radius, or less than the gravitational radius. We also calculated the minimum possible black hole mass and minimum black hole radius [1]:

$$\mathrm{Mmin} = 1.125 * 10^{30}\ \mathrm{kg}$$

$$\mathrm{Rmin} = 1.669 * 10^{3}\ \mathrm{m} = 1.67\ \mathrm{km}$$

Confirmation that black holes consist of quark-gluon plasma is the work of researchers from the University of Helsinki [2], where it is shown that neutron stars have "practically confirmed" cores consisting of quarks (the mass of a star is equal to two solar masses, quark matter is up to half the mass). It is quite obvious that the pressure in a black hole will be greater than in a neutron star, and therefore, all baryonic matter will be "crushed" to quarks, that is, to elementary particles.

From this it logically follows that since the pressure in ordinary stars is always less than the pressure in neutron stars and black holes, therefore, baryonic matter in classical stars cannot be "processed" into quark-gluon plasma. That is, classical quark stars cannot exist by definition.

But, if we admit a certain cosmic catastrophe, when part of a black hole or neutron star is thrown into space (part of the quark-gluon plasma is ejected), then we may well get an object of the "quark star" type. In order for it to be just a quark star, and not a black hole or a neutron star, it is necessary that the mass of such an object be several times less than the mass of our Sun (three or more times; ten times, ... a hundred times, etc.).

Actually, "...it is not yet clear whether the transition of matter to the quark state is reversible, that is, whether the quark matter will go back to neutron with decreasing pressure. As modeling shows, in the "quark gas" star, there must be a large number of s-quarks, so sometimes quark stars are also called "strange" stars..." [3].

Suppose that quark matter persists after a decrease in pressure, then we should fix a quark star with a mass 20 or 100 times less than the mass of our Sun... A rather unusual star, more like a fragment of a star, but still it may exist and radiate. Moreover, its radius should be much less than 1.67 km, approximately, several hundred meters. Now it becomes clear why quark stars are so hard to spot: they are very small. If they exist!

Note that the gravitational radius (Rs) and the radius of the quark-gluon plasma (R(liquid drop model)) for a black hole depend on the mass as follows [1]:

$$\mathrm{Rs} = 1.4831 * 10^{-27} * \mathrm{M}$$

$$\mathrm{R(liquid\ drop\ model)} = 1.5733 * 10^{-12} * M^{0.5}$$

From these formulas, it is obvious that with masses much less than the mass of our Sun, the radius of the quark-gluon plasma will be greater than the gravitational radius, that is, we will get a quark star. For example, suppose a quark-gluon plasma with a mass of 10^{28} kg was ejected during a space catastrophe. Then, the corresponding radii will be equal:

Rs = 14.831 m

R (liquid drop model) = 157.33 m

That is, the quark star will have a radius of only 157 meters. Such a space object will be very difficult to detect experimentally, even if it does not turn into baryonic matter.

1. Bezverkhniy V. D., Bezverkhniy V. V. Black Holes and Quark-Gluon Plasma. SSRN Electronic Journal (2020). http://dx.doi.org/10.2139/ssrn.3675936 https://vixra.org/pdf/2008.0126v1.pdf
2. Annala, E., Gorda, T., Kurkela, A. et al. Evidence for quark-matter cores in massive neutron stars. Nat. Phys. (2020). https://doi.org/10.1038/s41567-020-0914-9
3. Quark star. Wikipedia. https://en.wikipedia.org/wiki/Quark_star